CLAIMS

1. Method for the statistical multiplexing of flows of ATM cells originated by connections having different quality service classes, said flows generating transmission queues of cells (QUj) shared into functional blocks (Bi,...,Bm), and to some of said flows at least, being assigned a minimum guaranteed band on the multiplexed flow (LINK-OUT) and the possibility to share a residual band possibly available on the same flow through a function, hereinafter called Weighted Fair Queuing, or WFQ, which dynamically assigns opportune quantities of tokens, evaluated on statistical basis, to single transmission queues (QUj), that spend said tokens to have access to the residual band on the multiplexed flow (LINK-OUT), **characterized in that** said WFQ function includes dynamic assignment phases of opportune quantities of tokens, evaluated on statistical basis, also to said functional blocks (Bi,...,Bm), that spend said tokens to enable their transmission queues (QUj) to have access to the sharing of the residual band on the multiplexed flow (LINK-OUT), thus sharing among said functional blocks (Bj) the residual band on the multiplexed flow.

2. Statistical multiplexing method according to claim 1, characterized in that the phases of said WFQ function are cyclically repeated with renewal period of the cycle (TR) multiple integer of the transmission time of a cell (Tc) on said multiplexed flow (LINK-OUT), each cycle including the following steps:

a) assigning (INIZIALIZZA TK-CNT1,...,m) to at least some of said transmission queues (QU1, ..., QUz) a relevant number of tokens (N°TK(QU1), ..., N°TK(QUz)) proportional to the band of the relevant said flows;

b) assigning (INIZIALIZZA TK-CNT-B) to at least some of said blocks (B1, ..., Bm) a relevant number of tokens, (N°TK(B1) ,..., N°TK(Bm)) proportional to the aggregate band of the relevant component flows;

c) sharing (INIZIALIZZA FIFO WFQ-B) the indicators (B-ID) of blocks including transmission queues awaiting to be served in a high priority list (HP-FIFO), a low priority list (LP-FIFO), and a very low priority list (VLP-FIFO) belonging to a first set of lists (WFQ-B) controlled on FIFO basis;

d) sharing (INIZIALIZZA FIFO WFQ-Q) the indicators (Q-ID) of said transmission queues awaiting to be served within a high priority list (HP-FIFO), a low priority list (LP-FIFO), and a very low priority list (VLP-FIFO), individually belonging to second groups of lists (WFQ-Q) managed on FIFO bases, associated to the functional blocks;

e) scanning, at cell interval (Tc) and on the basis of tokens available, the lists of

indicators (B-ID) of said first set (SERVI HP-FIFO, SERVI LP-FIFO, SERVI VLP-FIFO) for the emission of indicators (B-ID) selecting functional blocks (Bj) having queues to serve;

f) scanning, at cell interval (Tc) and on the basis of tokens available, the lists belonging to said second sets of lists (WFQ-Q) selected, for the emission of relevant indicators (Q-ID) of transmission queues (QUj) enabled to transmit a cell on the multiplexed flow (LINK-OUT).

3. Statistical multiplexing method according to claim 2, characterized in that said step to scan e) includes the following steps:

- reading (READ HP-FIFO) an indicator (B-ID) from a high priority list (HP-FIFO) and serve (SERVI HP-FIFO) the block indicated, ending the scanning (È HP-FIFO VUOTA) with the emptying of said high priority list;
- reading (READ LP-FIFO) an indicator (B-ID) from a low priority list (LP-FIFO) and serve (SERVI LP-FIFO) the block indicated, decreasing, when appropriate, the tokens available and transfer the indicator (B-ID) of the block that has finished its tokens inside a very low priority list (VLP-FIFO), ending the scanning (È LP-FIFO VUOTA) with the emptying of said low priority list, or with the end of the renewal period (TR);
- reading (READ VLP-FIFO) an indicator (B-ID) from a very low priority list (VLP-FIFO) and serve (SERVI VLP-FIFO) the block indicated, ending the scanning (È VLP-FIFO VUOTA) with the emptying of said very low priority list, or with the end of the renewal period (TR).

4. Method of statistical multiplexing according to claim 3, characterized in that each said step to serve (SERVI HP-FIFO, SERVI LP-FIFO, SERVI VLP-FIFO) the blocks indicated in said lists having different priorities, also includes the step to reinsert one said block indicator (B-ID) in the origin list in case at least one cell to be transmitted is present in at least one queue (QUj) assigned to the selected block.

5. Statistical multiplexing method according to one of the previous claims, characterized in that said connections having service classes of different quality include some for which the peak cell-rate is guaranteed, and therefore involve flows which have not the opportunity to avail of said additional band possibly available on the multiplexed flow (LINK-OUT), said flows having peak cell-rate generating transmission queues allocated in a unique block that have service priority up to the emptying of the same.

6. Statistical multiplexing method according to one of the previous claims,

where some of said connections are supported by flows of ATM cells that require a control of the peak band such to prevent that a given maximum band value within said multiplexed flow (LINK-OUT) is exceeded, characterized by the fact to have recourse to a first timing that expands the emission intervals of at least some said indicators (B-ID) of the functional blocks (Bj) to limit the aggregate peak band of the group of connections belonging to the selected blocks.

7. Statistical multiplexing method according to claim 6, characterized in that said first timing is obtained at each cell time (Tc) an insertion location (N-SLOT-B) in a first calendar of an indicator (B-ID) of a selected block, the first calendar being read at the same writing time interval to extract a block indicator (Bj) that shall be actually selected at the present cell time (TNOW).

8. Statistical multiplexing method according to claim 6, or 7, characterized by the fact to have recourse to a second timing expanding the emission intervals of at list some of said indicators (Q-ID) of transmission queue to limit the peak band of the queues served.

9. Statistical multiplexing method according to claim 8, characterized in that said second timing is obtained calculating at each cell time (Tc) an insertion location (N-SLOT-Q) in a second calendar of one said queue indicator to serve (Q-ID), the second calendar being read with the same writing time interval to extract an indicator of the transmission queue (QUj) that shall be actually served at the actual cell time (TNOW).

10. Statistical multiplexing method according to claim 7, characterized in that said insertion of a first calendar of a block indicator (B-ID) is performed in parallel to said extraction.

11. Statistical multiplexing method according to claim 9, or 10, characterized in that said insertion in a second calendar of a transmission queue indicator (Q-ID) is made in parallel to said extraction.

12. Statistical multiplexing method according to any claim 7 to 11, characterized in that said indicators (B-ID, Q-ID) extracted from a common location (N-SLOT-B, N-SLOT-Q) of a relevant calendar, are extracted according to the FIFO method.

13. Statistical multiplexer of flows of ATM cells originated by connections having service classes of different quality, said flows generating transmission queues of cells (QUj) shared in functional blocks selected for the service, and at least some of said flows being assigned a minimum guaranteed band on the multiplexed flow

(LINK-OUT), and the possibility to share a residual band possibly available on the same flow, including:

a) a storage buffer of said transmission queues (QUj) of ATM cells:

b) means controlling the access to the buffer for the insertion or extraction of said cells;

c) counting means of the number of cells included in each one of said transmission queues;

d) execution means of a known technique, hereinafter called Weighted Fair Queuing, or WFQ, that dynamically assign opportune quantities of tokens, evaluated on statistical basis, to single transmission queues (QUj), spending said tokens to have access to the residual band on the multiplexed flow (LINK-OUT), **characterized in that** said execution means of the WFQ technique are modified (WFQ-CONTR, WFQ-B, WFQ-Q) in order to dynamically assign opportune quantities of tokens, evaluated on statistical basis, also to said functional blocks (Bi,...,Bm), that spend said tokens to enable their transmission queues (QUj) to have access to the sharing of the residual band on the multiplexed flow (LINK-OUT), thus sharing among said functional blocks (Bj) the residual band on the multiplexed flow.

14. Statistical multiplexer according to claim 13, characterized in that said modified execution means of the WFQ technique (WFQ-CONTR, WFQ-B, WFQ-Q) include:

a) a first storing structure (TK-CNT1,...,TK-CNTm) at disposal of each transmission queue (QUj) to store a relevant number of tokens (N°TK(QU1),...,N°TK(QUz)) proportional to the band of the relevant said flows, said first storing structure (TK-CNT1,...,TK-CNTm) being used as set of counters;

b) a second storing structure (TK-CNT-B) at disposal of each one of said functional blocks (B1, ..., Bm) to store a relevant number of said tokens (N°TK(B1),...,N°TK(Bm)) proportional to the aggregate band of the relevant component flows, said second storing structure (TK-CNT-B) that can be used as set of counters;

c) a first set of FIFO memories having different service priority (WFQ-B), that can be used to store the indicators (B-ID) of the functional blocks (Bi,...,Bm);

d) second sets of FIFO memories having different service priority (WFQ-Q), that can be separately used to store the indicators (Q-ID) of the transmission queues (QUj) belonging to one said relevant functional block (Bj);

e) a control unit (WFQ-CONTR) connected to the first (TK-CNT1,...,TK-CNTm) and

second (TK-CNT-B) storing structure reserved to the tokens, to said first (WFQ-B) and second sets of memories FIFO (WFQ-Q) reserved to the indicators, said control unit (WFQ-CONTR) being controlled by a program that assigns the relevant said quantity of tokens and regulates their consumption.

15. Statistical multiplexer according to claim 14, characterized in that said first set of FIFO memories (WFQ-B) and each second set of FIFO memories (WFQ-Q) having different service priorities, individually include a high priority FIFO memory (HP-FIFO), a low priority FIFO memory (LP-FIFO), and a very low priority FIFO memory (VLP-FIFO).

16. Statistical multiplexer according to any claim 13 to 15, characterized in that said modified means for the execution of the WFQ technique (WFQ-CONTR, WFQ-B, WFQ-Q) include also a counter of the real time that is initialized by said control unit (WFQ-CONTR) with a pre-set value, decreasing at each cell time (Tc), and therefore reinitialized after each reset, cyclically repeating the above mentioned steps; the real time counter being used by the control unit (WFQ-CONTR) to renew, at each initialization of the above mentioned counter, the writing of the initial number of said tokens reserved to the functional blocks (Bi,...,Bm) and to the transmission queues (QUj), within the first (TK-CNT1,...,TK-CNTm) and second (TK-CNTB) storing and count structure, respectively.

17. Statistical multiplexer according to claim 16, characterized in that at each initialization of said real- time counter, said control unit (WFQ-CONTR) renews its content of said high (HP-FIFO), low (LP-FIFO), and very low (VLP-FIFO) priority FIFO memories belonging to said first (WFQ-B) and second sets (WFQ-Q) of FIFO memories.

18. Statistical multiplexer according to claim 17, characterized in that during each said renewal time (Tr) said control unit (WFQ-CONTR) scans, at cell interval (Tc) and on the basis of available tokens, said first set of memories FIFO (WFQ-B) for the emission of an indicator (B-ID) for the selection of a functional block (Bj) having one queue at least to serve.

19. Statistical multiplexer according to claim 18, characterized in that during each said renewal time (Tr) said control unit (WFQ-CONTR) scans, at cell time interval (Tc) and on the basis of available tokens, one said second set of FIFO memories (WFQ-Q) associated to a functional block (Bj) selected, for the emission of an indicator (Q-ID) of a transmission queue (QUj) enabled to transmit a cell on the multiplexed flow (LINK-OUT).

20. Statistical multiplexer according to any claim 13 through 19, where said connections having service classes of different quality, include some for which the peak cell-rate is guaranteed, and therefore do not involve flows that have not the possibility to avail of said additional band possibly available on said multiplexed flow (LINK-OUT), said flows at the peak rate generating transmission queues allocated in a unique block, characterized in that said control unit (WFQ-CONTR) is additionally connected to a device (RT-FLAG) indicating the filling state of said unique block in such a way that the transmission queues of said unique block are served with priority until said indicator device (RT-FLAG) is active.

21. Statistical multiplexer according to any claim 13 through 20, where some of said connections are supported by flows of ATM cells requiring a control of the peak band such to prevent that a given maximum band value within said multiplexed flow (LINK-OUT) is exceeded, characterized in that it includes first timing means (SHAPER-B, SCHEDULER-B) that expand the emission intervals of at least some said indicators (B-ID) of the functional blocks (Bj) to limit the aggregate peak band of the group of connections belonging to the selected blocks.

22. Statistical multiplexer according to claim 21, characterized in that said first timing means (SHAPER-B, SCHEDULER-B) include a first traffic shaper (SHAPER-B) placed upstream a first scheduler with calendar mechanism (SCHEDULER-B), said first shaper (SHAPER-B) calculating at each cell time (Tc) an insertion location (N-SLOT-B) in the first calendar of an indicator (B-ID) of a selected block and writing the indicator (B-ID) in the first calendar at the calculated location, and said first scheduler (SCHEDULER-B) reading the first calendar at the same writing time interval to extract an indicator (B-ID) of the block (Bj) that shall be actually served at the actual cell time (TNOW).

23. Statistical multiplexer according to claim 21, or 22, characterized in that it also includes second timing means (SHAPER-Q, SCHEDULER-Q) that expand the emission intervals of at least some of said indicators (Q-ID) of the transmission queues (QUj) to limit the peak band of queues served.

24. Statistical multiplexer according to claim 23, characterized in that said second timing means (SHAPER-Q, SCHEDULER-Q) include a second traffic shaper (SHAPER-Q) placed upstream a second scheduler with calendar mechanism (SCHEDULER-Q), said second shaper (SHAPER-Q) calculating at each cell time (Tc) an insertion location (N-SLOT-Q) in the second calendar of an indicator (Q-ID) of transmission queue to serve and writing the indicator (Q-ID) in the second calendar at

the calculated location, and said second scheduler (SCHEDULER-Q) reading the second calendar with the same writing time interval to extract an indicator (Q-ID) of the transmission queue (QUj) that shall be actually served at the actual cell time (TNOW).

25. Statistical multiplexer according to claim 22, characterized in that said first shaper (SHAPER-B) operates in parallel to said first scheduler (SCHEDULER-B).

26. Statistical multiplexer according to claim 24, or 25, characterized in that said second shaper (SHAPER-Q) operates in parallel to said second scheduler (SCHEDULER-Q).

27. Statistical multiplexer according to any claim 22 through 26, characterized in that said indicators (B-ID, Q-ID) extracted from a common location (N-SLOT-B, N-SLOT-Q) of a relevant calendar, are extracted according to the FIFO method.